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Temporal signatures of auditory verbal hallucinations: An app-based experience sampling study

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1. Introduction

The assessment of auditory verbal hallucinations (AVHs) has traditionally been conducted through (semi-)structured interviews, such as the Positive and Negative Syndrome Scales (PANSS; Kay, Fiszbein, and Opler, 1987) and the Psychotic Symptom Rating Scales (Haddock, McCarron, Tarrier, and Faragher, 1999) in patients and the Launay Slade Hallucination Scale (Launay & Slade, 1981; Larøi & Van der Linden, 2005) in the general population. However, since standard assessments rely on retrospective and summative reports and thus on the person’s accurate memory and capability to estimate the average experience of past hallucination episodes (usually a summary of the last week), the extent to which AVHs are stable or vary across the course of hours or days is currently unknown. To fill this knowledge gap, the current study used an in-house developed mobile application (app) to capture AVHs as experienced in the moment in which they occur. This approach has recently been termed “digital phenotyping” (Insel, 2017; Torous & Keshavan, 2018).

The aim of the present study was to explore the relationships between five key AVH-dimensions (cognitive control, emotional content, spatial localization, intensity, and severity) and for the first time, the temporal patterns of these dimensions.

2. Method

Twenty patients (12 males, 8 females, mean age: 35.5 years; 10 Norwegian patients; 10 Finnish patients) with a diagnosis of schizophrenia (ICD-10; F20) and who reported experiencing hallucinations (according to PANSS item P3 Hallucinations) were recruited for the study. The data collection was set to a maximum of four weeks. However, in many cases it was shorter (see Figure S1). The study was approved by the regional ethical committees responsible for the respective location of the data collection. Participants were instructed to report about their AVHs in the moment in which they occur (event-related design). To do this, participants used an in-house developed app which consisted of a series of five questions, each representing a separate AVH-dimension (see Figure 1). Participants responded on a visual analogue scale (VAS) by moving their finger on a horizontal slider. The score for each answer ranged from zero at the far left of the VAS and continuously increasing to one at the far right of the VAS.

Insert Figure 1 about here

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3. Results

The average number of days that participants reported on their hallucinations was 19.5 days (max 30; min 6). The average number of sessions per participant was 74.8 sessions (min 24, max 162), of which 64.2% were completed. 69.4% of the completed sessions were initiated by the patient.

The results from the general linear mixed model analysis showed that all AVH-dimensions were significantly related to each other except for the localization dimension, which was only related to the intensity dimension (see Table S1). The direction of the relationships revealed that, when AVHs had more positive content, they were also experienced as less disturbing, more controlled, and quieter. Moreover, more cognitive control of the AVHs was related to less disturbing and quieter AVHs. Finally, more internal AVHs was associated with quieter AVHs (see Figure S2).

Also, with regard to temporal effects, a significant interaction between the *VAS index-score* and *day-of-week* [F(24,1808)=1.72, p = .017] was found. Post-hoc analyses revealed that the interaction was driven by (a) the emotional content dimension, that is, significantly more positive AVHs on Fridays compared to Mondays (p = .006), Tuesdays (p = .041), and Thursdays (p = .026), and (b) the severity dimension, that is, significantly more disturbing AVHs on Saturdays compared to Tuesdays (p = .008), Thursdays (p = .024), and Fridays (p = .001). In addition, a significant interaction was observed between the *VAS index-score* and *time-of-day* [F(12,1762)=1.79, p = .045]. This interaction was driven by AVHs being rated as louder in the morning (6 am - 12 am) compared to the afternoon (12 am – 6 pm; p = .005) as well as compared to the evening (6 pm – 12 pm; p = .009).

4. Discussion

The present study showed for the first time that AVH-dimensions fluctuate between short time-intervals (within hours) and in doing so revealing effects of day-of-the-week and time-of-day.

Our finding that more positive AVHs are associated with more control over AVHs and less distress is in line with previous research which showed that content and control are important factors in differentiating between individuals experiencing AVHs in the general population (without a psychiatric diagnosis) and patients experiencing AVHs (with a psychiatric diagnosis) (Daalman et al., 2011; Johns et al., 2014). It appears that when AVHs are more controllable, they are more likely to have positive content, and this may be a marker of non-clinical AVHs. Conversely, the negative emotional valence of experienced AVHs in clinical populations may have an origin in lack of cognitive control, perhaps due to weak prefrontal inhibition (for a review see Larøi et al., 2019).

The day-of-the-week effect is in line with research on mood in healthy individuals. In a large scale-survey study (N = 340,000), Stone, Schneider and Harter (2012) reported strong support for what is called the “Thank God it’s Friday” effect, that is, mood tends to be better on Fridays and Saturdays than during the rest of the week. Similar to the findings in the present study, albeit for symptoms of paranoia and negative/positive affect, Oorschot et al. (2012) showed that day-to-day fluctuations were related to contextual factors such as being alone vs. being with family. Together these findings suggest that the current mood state is manifested in the content of the AVH.

With regard to the time-of-day effect, it could be speculated that louder AVHs occur in the morning because this is usually before medication is taken. We also found that AVHs are perceived to come from an external source with increasing intensity (loudness). This suggests that perceived loudness of an AVH may play a crucial role in the misattribution error, that is, internally generated cognitive events are falsely attributed to an external source (see Woodward and Menon, 2013. Along this line, a study by Cuevas-Yust (2014) found that schizophrenia patients experiencing AVHs also reported hearing ordinary thoughts at the same volume as their AVHs and spoken words. In contrast, healthy participants and schizophrenia patients without AVHs reported spoken words as louder than their own thoughts. In this respect, perceived loudness has been linked to reduced activation in distributed brain networks involved in inner speech processes (Vercammen, Knegtering, Bruggeman, and Aleman, 2011).

Table captions:

Table S1: Relationships between AVH-dimensions. b-values are unstandardized coefficients. Numbers in bold indicate significant difference.

Figure legends:

Figure 1: Illustration of the app containing the initial question (“Are you hearing voices right now?”) and the five questions about AVH-dimensions.

Figure S1: Individual patient profiles showing the fluctuations of the AVH index-scores (y-axis) and the number of days in study (x-axis).

Figure S2: The colored lines indicate significant associations between the respective AVH-dimensions. + indicates a significantly positive association between the AVH index-scores.

References:

Cuevas-Yust, C., 2014. Do Thoughts Have Sound? Differences between Thoughts and Auditory Hallucinations in Schizophrenia. *The Spanish Journal of Psychology. 17*, E27.

Daalman, K., Boks, M. P., Diederen, K. M., de Weijer, A. D., Blom, J. D., Kahn, R. S., Sommer, I. E., 2011. The same or different? A phenomenological comparison of auditory verbal hallucinations in healthy and psychotic individuals. *J Clin Psychiatry. 72*, 320-325.

Haddock, G., McCarron, J., Tarrier, N. Faragher, E.B., 1999. Scales to measure dimensions of hallucinations and delusions: the psychotic symptom rating scales (PSYRATS). Psychological Medicine. 29, 879-889.

Insel, T. R., 2017. Digital Phenotyping: Technology for a New Science of Behavior. *JAMA. 318*, 1215-1216.

Johns, L. C., Kompus, K., Connell, M., Humpston, C., Lincoln, T. M., Longden, E., Preti, A., Alderson-Day, B., Badcock, J. C., Cella, M., Fernyhough, C., McCarthy-Jones, S., Peters, E., Raballo, A., Scott, J., Siddi, S., Sommer, I. E., Laroi, F., 2014. Auditory verbal hallucinations in persons with and without a need for care. *Schizophrenia Bulletin. 40 (suppl. 4)*, S255-264.

Kay, S.R., Fiszbein, A., Opler, L.A., 1987. The positive and negative syndrome scale (PANSS) for schizophrenia. Schizophrenia Bulletin. 13, 261-276

Larøi, F., Thomas, N., Aleman, A., Fernyhough, C., Wilkinson, S., Deamer, F., McCarthy-Jones, S., 2019. The ice in voices. Understanding negative content in auditory-verbal hallucinations. *Clinical Psychology Review*. *67,* 1-10.

Larøi, F., Van der Linden, M., 2005. Normal subjects' reports of hallucinatory experiences. *Can. J. Behav. Sci*. *37*, 33–43.

Launay, G., Slade, P., 1981. The Measurement of hallucinatory predisposition in male and female Prisoners. Personal. Individ. Differ. 2. 221–234.

Oorschot, M., Lataster, T., Thewissen, V., Bentall, R., Delespaul, P., Myin-Germeys, I., 2012. Temporal dynamics of visual and auditory hallucinations in psychosis. *Schizophrenia Research. 140*, 77-82.

Stone, A. A., Schneider, S., & Harter, J. K., 2012. Day-of-week mood patterns in the United States: On the existence of ‘Blue Monday’, ‘Thank God it's Friday’ and weekend effects. *The Journal of Positive Psychology. 7*, 306-314.

Torous, J., & Keshavan, M. (2018). A new window into psychosis: The rise digital phenotyping, smartphone assessment, and mobile monitoring. *Schizophrenia Research, 197*, 67-68.

Vercammen, A., Knegtering, H., Bruggeman, R., Aleman, A., 2011. Subjective Loudness and Reality of Auditory Verbal Hallucinations and Activation of the Inner Speech Processing Network. *Schizophrenia Bulletin. 37 (5)*, 1009-1016.

Woodward, T.S., Menon, M., 2013. Misattribution models (II): Source monitoring in hallucinating schizophrenia subjects, in Jardri, R., Cachia, A., Thomas, P., Pins, D. (Eds.), The Neuroscience of Hallucinations, Springer, New York, pp. 169-184.